PALM AND SOLE STUDIES.

HARRIS HAWTHORNE WILDER.

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I. INTRODUCTION.

In the study of the details of the configuration of the friction-ridges found covering the surfaces of human palms and soles there opens up a field of the greatest value for the biologist. Varying greatly individually, though constant throughout the life of a given individual; still following the lines laid down for them in more primitive mammals, yet modified and varied as the result of mechanical causes; showing markedly and with certainty a direct inheritance from the immediate parents as well as from generations more remote; they may be used with profit by the morphologist, the ethnologist, or the student of genetics, while, as the surest and most positive characters of an individual, they may serve the authorities in the identification of a human body, living or dead.

A great advantage in the study of these parts lies in the ease with which a print of the surfaces may be taken, thus furnishing a permanent record, accurate in even the minuter details, and easily filed away. These prints, with the ridges marked in black upon a white background, and reduced to a perfectly plane surface, are much easier to study than are the real objects; laid out upon a large table they may be compared with ease; they are always ready for reproduction where desirable. Undeniably the patterns are complicated, and many new conceptions, and the new terminology which expresses them, confront the beginner, as in any new field; but this much once accomplished

there opens up to the investigator an almost endless series of new phenomena the study of which, in the few years during which the subject has received special attention, has been no more than begun.

As this paper is intended in part as an invitation, or perhaps a propaganda, for more work in this subject, a bibliography of the entire subject is appended, with some suggestions as to the character of the separate titles. It may not come amiss, also, to give in this place a key to the method of formulation now in use, which, although somewhat artificial in the sense that it does not have much morphological significance, is a convenient way in which to express the fundamental conditions found in a given palm or sole, and as such, has already been extensively used.[1]

In the palm the starting-points of this system are four *triradii* (Galton's *deltas*) which lie at the bases of the four fingers, and may be designated as A, B, C, and D, the first situated beneath the index finger, and so on. As in all triradii, these points form each the meeting place of three radiating lines, at approximately 120° from each other, and of these three *radiants* two short ones pass obliquely upwards (distally), defining a small *digital area*, while the third follows a longer and quite variable course across the palm. These latter are the four *Main Lines*, designated by the same letters as are used for their triradii of origin, and as their position indicates the configuration of the entire palm, a simple method of describing their course is of first importance.

To "interpret" a given palm it is first necessary to locate the four digital triradii, A, B, C, and D, and then to trace from these centers their three radiants, and more especially the main lines, following them across the palm wherever they may lead, never crossing a ridge. Often, in this pursuit a single ridge may be followed almost the entire distance; again, the ridge that is being followed may come to an end, yet the direction be immediately taken up with a new one, upon which the line may be continued. Where a ridge forks, and thus allows two or more possible courses, the most distal one should be taken. If, now, these courses be

[1] Cf. the recent papers of Schlaginhaufen, 1906; Loth, 1906, and the two papers of Wilder on "Racial Differences," 1904, 1913; cf. also the exposition of the method in Martin's new "Lehrbuch der Anthropologie," Jena, 1914, pp. 360–367.

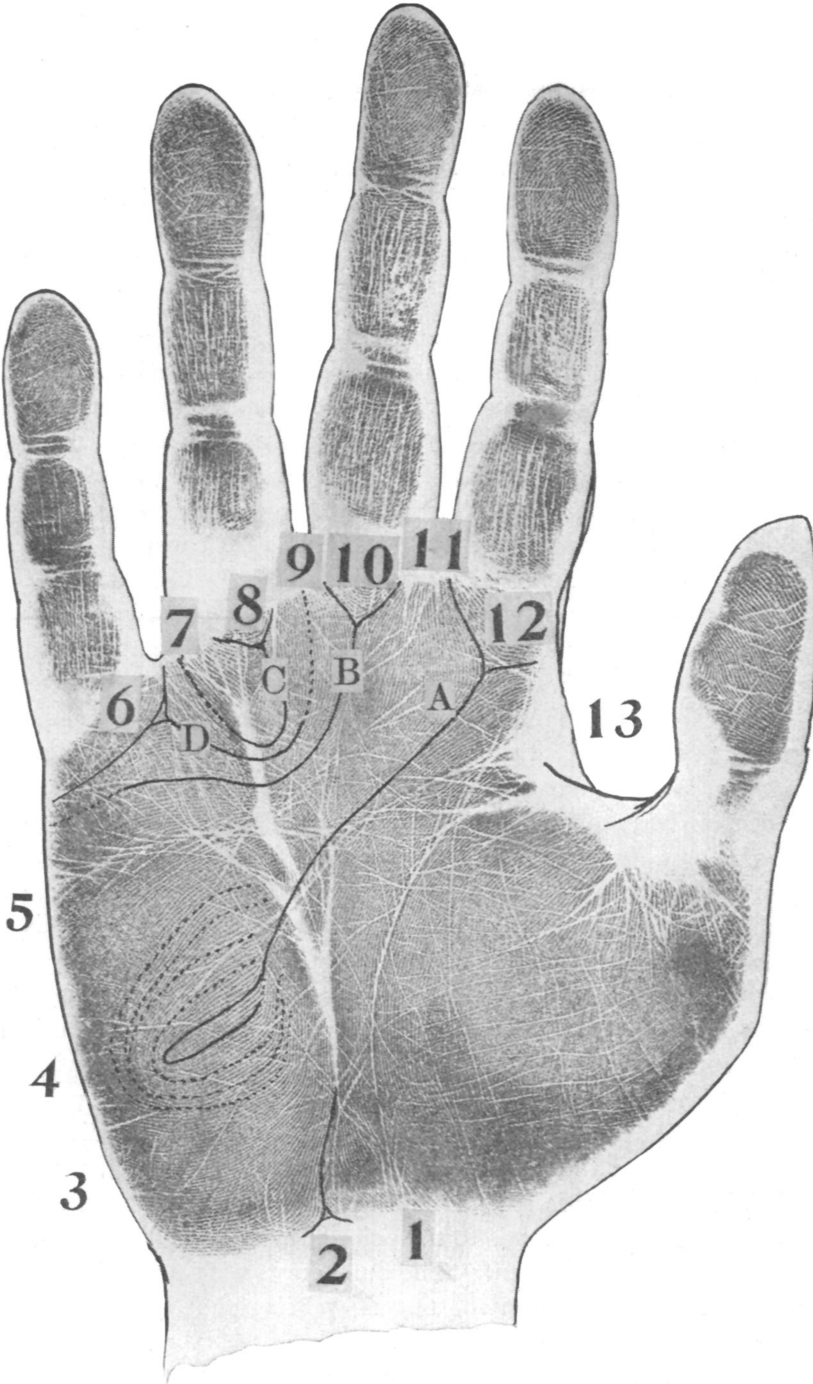


FIG. 1. Print of a left hand, showing method of "interpretation," as explained in the text. The print shows the four *main lines*, and the numbers arbitrarily assigned to the different parts of the margin. Formula: 9·7·5·4. Line *A* becomes involved in a hypothenar pattern, giving it the value of 4.

marked, while being followed, by a colored pencil, of red, or some other conspicuous color, or by ink, the palm will appear like those shown in Figs. 1 and 2, except that the result will be naturally more or less unlike either model.

As the triradii of origin never vary much in position, the general course of the main lines may be given by determining with some precision their termini, that is, the points at which they issue from the margin of the friction-skin area. This is easily accomplished by designating the several regions and points along the margin by an arbitrary system of numbers, as here shown, using the numbers 1 to 13. In this the more definite points, like triradii or pattern-cores, are designated by even numbers, and the intervals between these by odd. Thus 2 indicates the *carpal triradius*, lying on the proximal margin at the middle of the wrist. When not actually present, the location of this point is equally well determined by a parting of the lines towards the radial and ulnar sides. 4 indicates the *hypothenar* pattern, a conspicuous feature present in about 20 per cent. of white hands; when the pattern is wanting, this number is not used. The numbers 6, 8, 10, and 12 indicate the four digital triradii, but in the reverse order, beginning with triradius *D*. The odd numbers are not so precise, and designate the entire lengths of margin between the points just mentioned. 1 means any termination upon the radial side (thumb-side) of the carpal triradius; 3 begins at this latter point and runs up along the ulnar side as far as the hypothenar pattern, and 5 lies between this pattern and triradius *D* at the base of the little finger. When an hypothenar pattern is not indicated the distinction between 3 and 5 is somewhat uncertain, but in general, if the entire outer margin of the palm between the lower outer corner (proximal ulnar) and triradius *D* be divided into thirds, the lower, or proximal third is 3, while the distal two thirds are 5. The boundary between these two numbers thus corresponds to the point of location of 4 (hypothenar pattern) when present. The numbers 7, 9, 11 and 13 designate the spaces between the fingers, 7 being that between the little- and ring-fingers, and so on.

Thus, given these arbitrary values for the parts of the margin, it will be seen that in Fig. 1, line *D* crosses the margin at 9, *C* at 7, and *B* very high up along 5. Line *A* becomes involved in

the hypothenar pattern, indicated by the digit 4. The entire formula is thus, in the natural order, 4·5·7·9. In Fig. 2 lines *B* and *C* become confluent, so that the termination of each is designated by the number indicating the origin of the other, and the formula

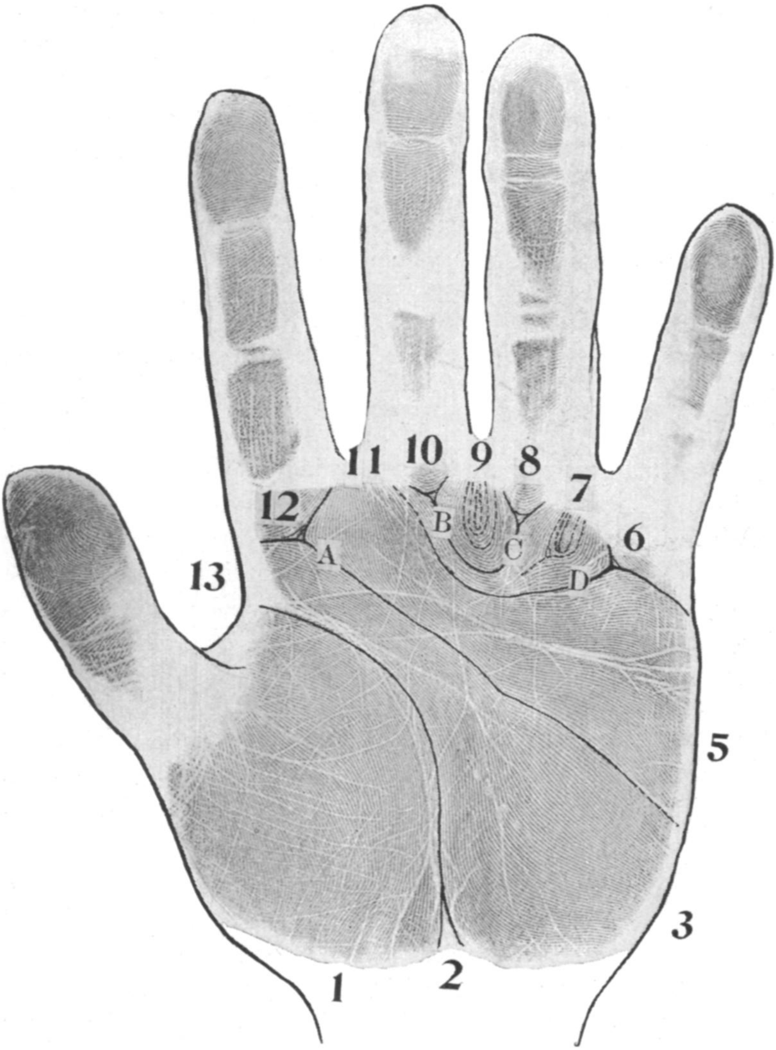


FIG. 2. Print of a right hand, marked as in Fig. 1. Formula: 11·10·8·5. Here the main lines *B* and *C* are confluent, and may each be considered to end in the triradius of origin of the other; that is, line *B* ends in triradius *8*, and line *C* in triradius *10*. The third and fourth interdigital patterns are present, the latter with a triradius belonging to it. These features may be added to the formula in giving a complete description.

will read 5·8·10·11. In this hand, also, is shown a case of divergent ridges along the course of line *A*, a common phenomenon, so that by following different ridges the line might be made to terminate almost anywhere along a considerable extent of margin. Following the rule above stated, however, that of carrying a line as far distally (towards the finger-tips) as possible, the line is made to terminate at 5.

In this way any human palm may be formulated by the use of four numbers, which indicate the conditions so nearly that one cannot be far out of the way if he should try and draw a given palm from the formula alone. This can be easily proven by anyone who knows the system and makes the attempt, using the formula only, and withholding the original print until the drawing is completed. This formula makes no attempt to indicate any features other than the course of the four main lines, yet, in point of fact, the presence of a pattern is sometimes indicated, as in the case of Fig. 2, where the fusion of lines *B* and *C* encloses a small area between the middle- and ring-fingers, and makes a looped pattern there a necessity.

When a large number of formulæ are accumulated they may be readily arranged in numerical order, subdividing first by the first number, and so on. For practical purposes, however, it is found better to reverse the entire formula, beginning with the number representing the course of line *D*, since with this latter there is not only more precision in termination than in the case of line *A*, but also line *D* is more variable, and thus furnishes more classes for the first subdivision. Thus the formulæ for the two cases here illustrated should read respectively, 4·5·7·9 and 11·10·8·5, the first coming before the second in a numerical list.

Corresponding to the results of a morphological study of the *patterns*, which shows them to have first developed on the raised surfaces of the eleven typical pads (Whipple, 1904), traces of this number are to be expected in their proper places. The five apical patterns appear on the balls of the five digits, the center or core of each coinciding with the rounded apex of the raised area. In their most primitive form they appear as concentric circles or ovals, or some modification of this form, limited by two triradii (deltas), the "*whorls*" of the finger-print system; the reduction of either one of the original triradii transforms the

whorl into a *loop*, ulnar or radial in accordance with the triradius that is suppressed; and this figure in turn becomes an *arch* by the suppression of the remaining triradius. The low arch, without appreciable core, is thus the final stage in the reduction process of a finger pattern. The fact that all possible stages along several lines of degeneration are found in man indicates the reduction in functional value as friction organs of these once so vital parts.

The six patterns of the palm proper consist of the four *interdigitals*, lying just proximal to the intervals between the fingers; the *thenar*, and the *hypothenar*. Of the four interdigitals the first (at the radial end of the series) lies below the wide interval between thumb and index finger, and is found usually in close connection with the thenar, the two forming loops opening in opposite directions, and with two triradii between them. This pattern-complex is rare in the white race; but much more frequent in some others (*e. g.*, the Maya-Quichés of Yucatan; Wilder, 1904). The three remaining interdigitals appear below the finger intervals, the second lying between triradii *A* and *B*, the next (third) between *B* and *C*, and the fourth between *C* and *D*. The one between triradii *A* and *B* (second) is the rarest of the three and the fourth, between *C* and *D*, is the commonest. Furthermore, this last is frequently provided with a triradius of its own, aside from *C* and *D*, a peculiarity occasionally, but not so frequently, met with in the other cases. The third pattern, between *B* and *C*, is liable to be confused with a "false pattern" caused by certain configurations of the ridges of the palm, but easily distinguished from the real one by its position in a depression rather than on an elevation (Whipple, 1904). The three mounds of this region are easily seen in most hands by bending the fingers back and looking across the palm in various directions. They are the plainest in children and in the fetus they are often extremely conspicuous (Retzius, 1904).

As might be expected, a human hand presenting all eleven patterns is quite rare, yet does occur. Such a case, found in the right hands in twin boys, has been already figured and described by the writer.[1]

As each of the four interdigital pads (or patterns) possesses typically three triradii of its own, with four for the third, it is

[1] Wilder, *Anat. Anz.*, Bd. XXXII., 1908, pp. 194, 195.

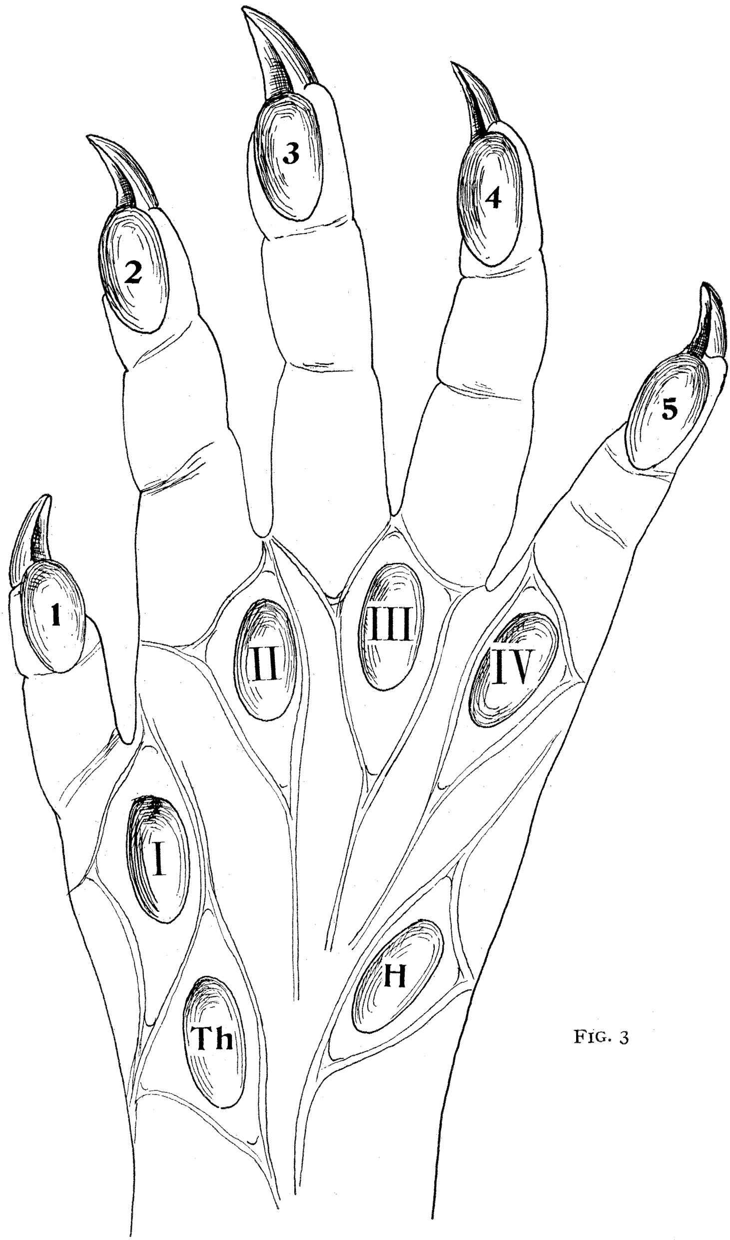


FIG. 3

FIGS. 3–5. Diagrams giving the morphological explanation of the friction-ridge configuration as found in the Primates, and especially in man. Fig. 3 represents the condition in primitive walking mammals, and follows closely the condition

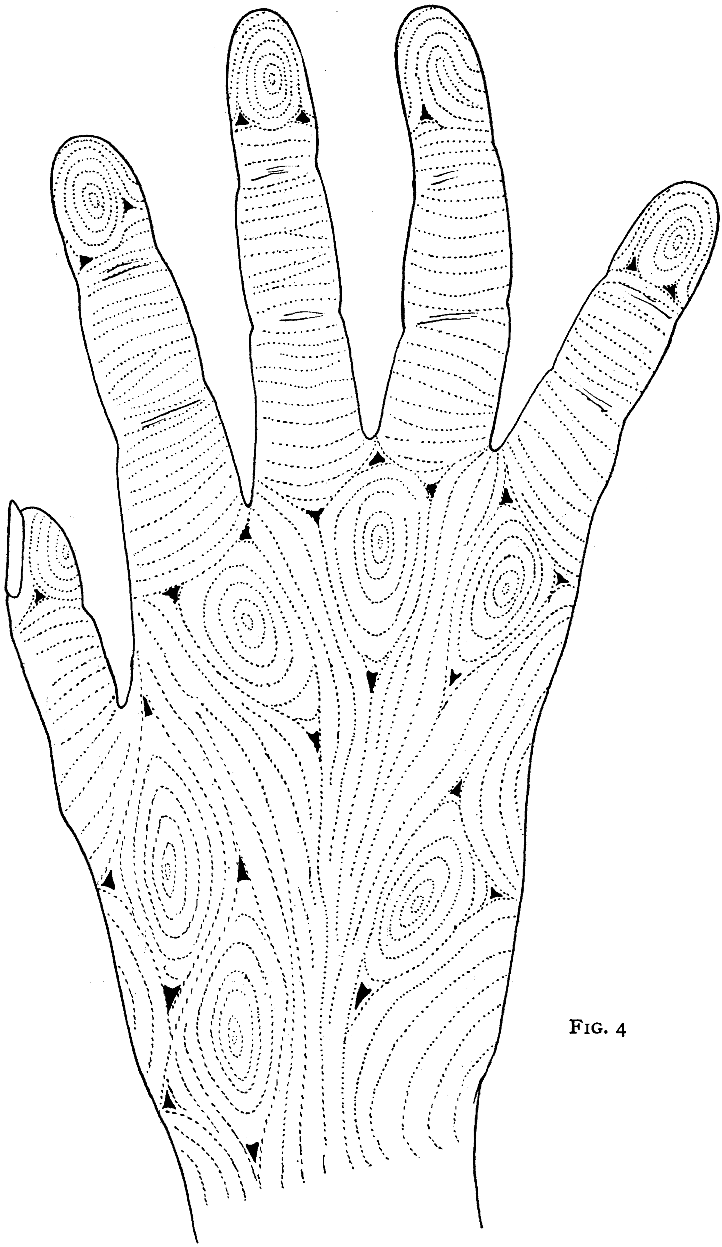


FIG. 4

found in *Microtus*, a field mouse and *Crocidura*, a shrew. The contact with the ground comes upon eleven walking pads; *five* apical or terminal, 1–5, *four* interdigital, I.–IV., a thenar, Th, and a hypothenar, H; *eleven* in all. These are surrounded by folds of skin, two for the apical pads, four for the third interdigital, and three

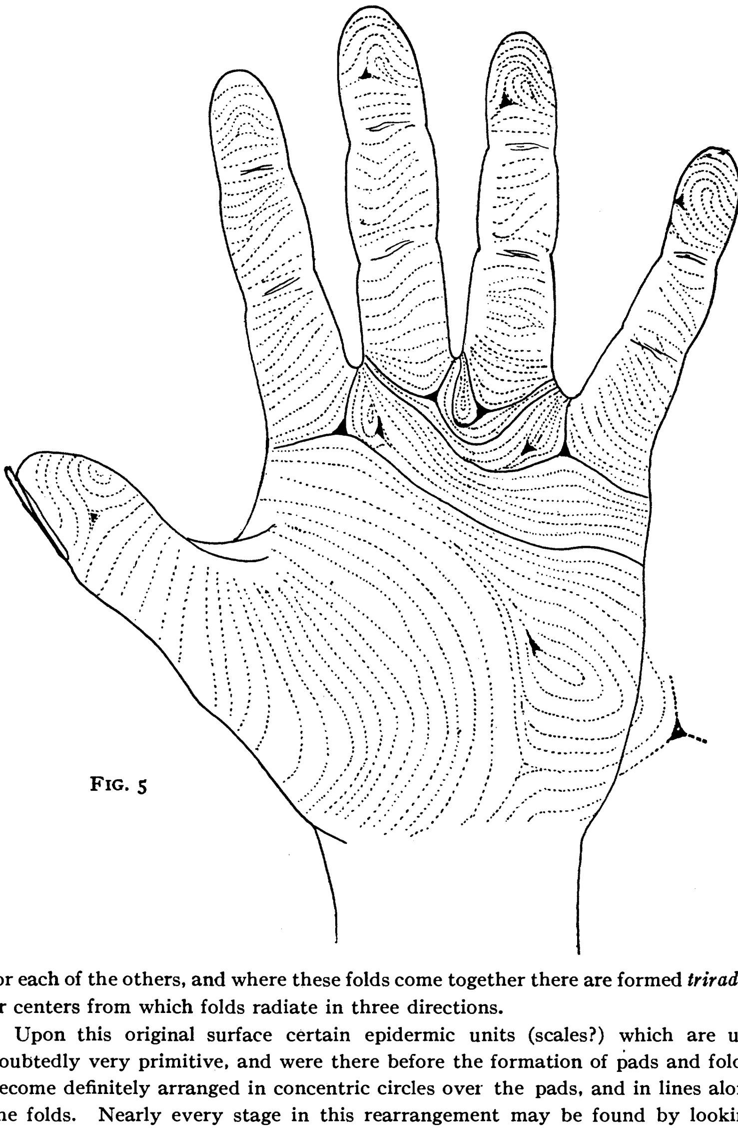


FIG. 5

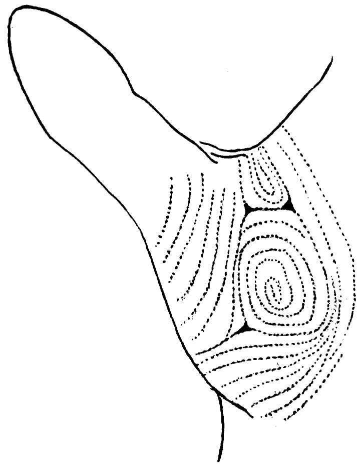
for each of the others, and where these folds come together there are formed *triradii*, or centers from which folds radiate in three directions.

Upon this original surface certain epidermic units (scales?) which are undoubtedly very primitive, and were there before the formation of pads and folds, become definitely arranged in concentric circles over the pads, and in lines along the folds. Nearly every stage in this rearrangement may be found by looking over the more primitive mammals, especially marsupials and lemurs. The separate rows of units tend to unite to form ridges, which possess an important function in increasing the friction, and thus preventing slipping.

In monkeys, Fig. 4, the pads and folds are flattened down to an approximately level surface, but the arrangement of the ridges still indicates the former condition. The *relief* has become a *picture*.

In man, Fig. 5, the reduction in functional importance of these friction-ridges allows all forms of degeneration, both in the individual patterns and in the ridges

FIG. 5*a*.



as a whole. There is also shown a marked tendency for all the ridges to shift from the longitudinal position of the apes to one more nearly transverse, and this tendency is much more marked in right than in left hands, evidently corresponding to use, and recording the change from the grasping of tree boughs to the holding of tools and other objects.

While all degrees of the loss of the original configuration and the assumption of transverse ridges may be found in different human hands, it is seldom that so many of the mound patterns are retained as in Fig. 5 (Coll. No. 90). The formula, however, 11·9·7·5, indicated the establishment of the transverse position in the interdigital region. Fig. 5*a* shows a very primitive Thenar region in a Liberian negro. (Coll. No. 571, taken by F. Starr.)

evident that in the human species a very considerable reduction of these points has taken place. There are left in all cases, however, the four main triradii, which are so constant as to allow their use as the starting points in palm formulation although it is by no means certain that they are in all cases strictly homologous. Thus, from Figs. 3 and 4 it is seen that the second interdigital pattern has originally two distal triradii, either of which might persist as triradius *A*, and it is likely that the one that appears is sometimes one and sometimes the other of the original two. Other of the missing triradii appear occasionally somewhat lower down on the palm (proximal to the pattern) especially in connection with the fourth pattern.

A definite hypothenar pattern appears on about 20 per cent. of hands of the white race, but the occurrence differs considerably racially and in some may be either more or less frequent. It is occasionally found in its more primitive form, as a whorl with

the three original triradii, but it displays a tendency to become drawn out along one axis and form an extensive spiral or S-formed figure.

As is well known, the exact and detailed configuration of the five apical patterns, the "finger-prints" of identification bureaus, was employed by the late Sir Francis Galton (1892, 1893, 1895,

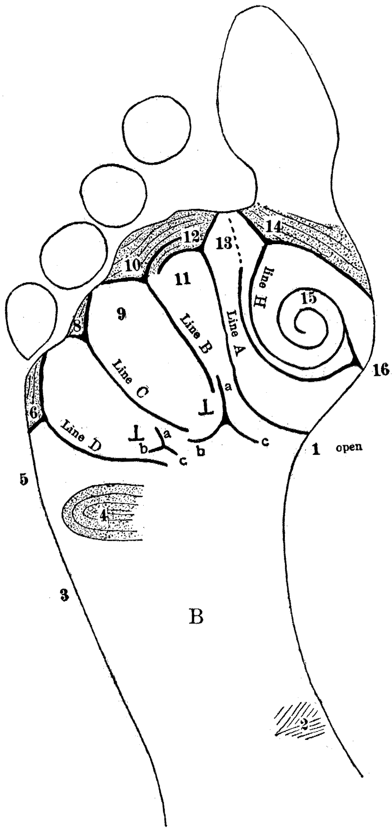


FIG. 6. Diagram of a human sole, with the margins numbered to correspond to the palms in Figs. 1 and 2, and marked with the *main lines*. From an article by the author in *Pop. Sci. Monthly* for September, 1903. By permission.

etc.) as the basis for his system of personal identification, and, within the last twenty years, has become scientifically developed by certain police investigators, notably Sir Edward Richard Henry. At the present time the "finger-print system" has been introduced into all civilized countries, and its scope is steadily increasing. As the friction-skin configuration offers an abso-

lutely sure test, and the only one, for the identification of a human body, alive or dead, it is certain that this use of the apical patterns will be followed by a similar employment of the entire palmar and plantar surfaces, as advocated by the present author since 1902, and at this writing it is a pleasure to note that sole-prints have recently been put in use in a Chicago maternity hospital for the identification of the babies.

Something on the frequency of occurrence of the six patterns upon the palm has been done in connection with racial differences in friction-skin configuration[1] and their progressive degeneracy from the simian type has been followed, in some cases along several lines, by Miss Whipple (1904, pp. 341–350).

The friction-skin configuration of the sole shows a much greater range of variability than is seen in the palm, and correspondingly its formulation presents a more serious problem. When the print indicates the four main triradii it is possible, of course, to draw the same four main lines, *A*, *B*, *C*, and *D;* using the same arbitrary numbers to designate marginal features (Fig. 6), yet this method is unpractical from a number of causes. In the first place the four essential triradii lie up in the hollow between the ball and the toes, and quite often come beyond the usual contact area, and thus are not seen in a print. Again, they are by no means as constant as in the hand, being occasionally replaced by other triradii which have survived instead of these; and still again, when the main lines are traceable, they quite often assume near their free ends a parallel course and terminate close together along the margin designated by the digit 1, thus giving little or no variety to the formula (1·1·1·1).

It has thus seemed more expedient to employ a distinctly different scheme for sole formulation, as illustrated in Figs. 7 and 8. The print is interpreted, that is, is marked off into areas, by the use of the main lines as in the palm, but as the lines themselves are not used otherwise than as boundaries, the tracing of their course is not so critical. Where all four main triradii are present as in Fig. 7, this interpreting is a simple matter; yet there are numerous cases in which one or more of the triradii lie above (distal to) the contact area, as in the case of triradius *C* of Fig. 8. Here there is, however, some divergence of the ridges at the upper

[1] Wilder, *Amer. Anthrop.*, 1904, 1913.

margin, sufficient to indicate the position of the line approximately, and the case is assisted by the presence of a "lower" or proximal triradius, one radient of which practically coincides with the supposititious *C* line. Thus between the two a boundary is fixed between the areas of the fourth and the third interdigital patterns, while the second, and the boundary between it and the third are definitely indicated by means of the main triradii.

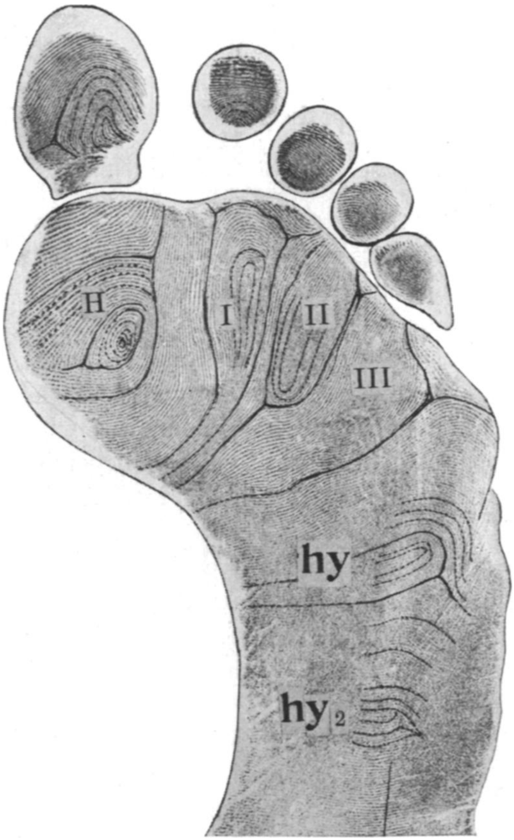


FIG. 7. Print of a right sole, showing the method of dividing the "ball" into its four interdigital areas, each of which may be separately described by formula. This method is fundamentally different from that used for the palm, as shown in Figs. 1 and 2. Formula: $W \cdot L \cdot Cl \cdot O \cdot H \cdot H2$.

Now in all cases, whether the limits are precise, as in Fig. 7, or approximate, as in Fig. 8, the "ball" of the foot is easily divided up into areas corresponding to the four interdigital patterns. Of these the first, beneath the great toe, or rather

beneath the interval between this digit and the next, is the largest, and is usually covered with a definite arrangement of ridges, the hallucal pattern. It will be noted that this, the most important of the four in the foot, is the same one that, in the hand, appears only as an adjunct of the rare thenar pattern, and is thus of little importance. This difference is plainly the result of the difference in function and use of foot and hand, as in the former the main work is performed by the heel, and by the four interdigital areas placed in a row close together, while of this row the inner end, below the great toe, is used the most.

The descriptive formulation of the sole configuration is thus

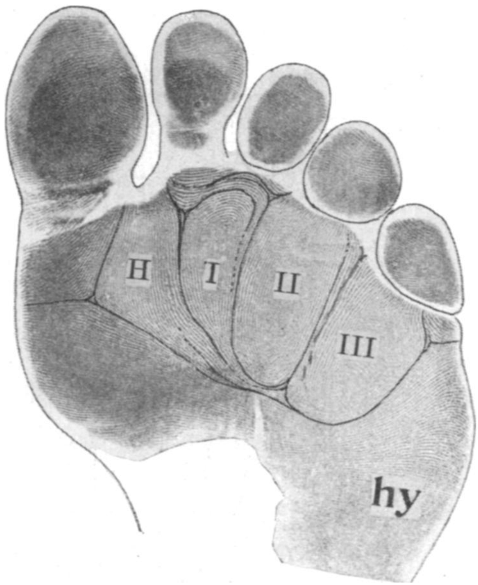


FIG. 8. Print of a right sole, showing a second case of the method of interpretation used in the preceding figure. This print exhibits the unusual case of the effacement of a definite hallucal pattern, similar to the sixth type shown in Fig. 9. Formula: $BC \cdot L \cdot Cl \cdot Cl \cdot x$.

seen to be most advantageously accomplished by using the *areas* rather than the *lines*, and describing the condition of the patterns found upon them. To begin with, the hallucal pattern, which is used for the classification of soles into primary groups, is found in its most primitive form as the *whorl*, equipped with its three typical triradii, *A*, *B*, and *C* (Fig. 9). Either triradius may be wanting, thus allowing the ridges to open, or gush out, to use a

figure which has no morphological significance, in the direction of *A*, or *B*, or *C*. The whorl, in formula writing, may be designated as *W*, and the three derived types just given, may be distinguished by the triradius that is wanting, as *A*, *B*, or *C*, respectively. Aside from these, there are compound types, where two of the triradii fail, and where the ridges flow out in two directions. Of

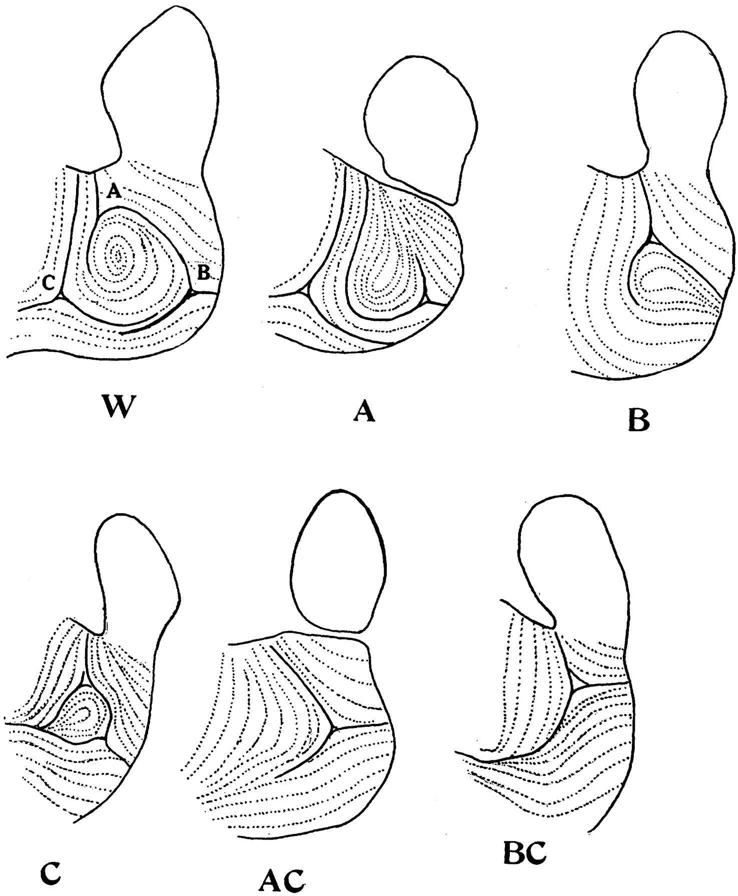


FIG. 9. Diagram showing the types of hallucal pattern. *W* is a whorl, with the three triradii all present, *A*, *B*, and *C*. In type *A* triradius *A*, the distal one. is lost, and the ridges flow out between the first and second digits. In type *B* the triradius of the name, the tibial one, is lost while *A* and *C* remain, and in type *C*, the fibular triradius (*C*) is lost, or nearly so, giving an outlet for the ridges in that direction. Types *AC* and *BC* may be interpreted as compound types, explicable from the others, especially *C*, where the two triradii *A* and *C* lie near together. In *AC* the remaining triradius is assumed to be *B*, and in *BC* it is *A*. In *AC* the remnant of the pattern lies to the left of the triradius; in *BC* below it.

these the possible types are *AC*, *BC*, and *AB*, the distinctions between which are obvious. The type shown in Fig. 7 is virtually a whorl (*W*), although it is not typical; while the type of Fig. 8 is extremely rare, and is most probably interpreted as an *AB*, with some possibility that it is rather a *BC*. The three remaining areas are conveniently designated as I., II., and III., respectively, and are characterized as either *open* (*O*), or *closed* (*Cl*) in accordance with the condition of their proximal ends. Thus, in Fig. 7, I. and III. are open, that is, they reach the inner margin, while II. is clearly closed; in Fig. 8 all three are closed, but I. is open for some distance, curves around the base of II., and abuts finally against the side of III. Occasionally, too, an area may be closed at the top, also, as area I. in both figures given, and sometimes the ridges of two areas flow into each other, that is, they are confluent. A confluence is easily marked by the designations of the areas involved, united by a + sign, as, I.+III.; I.+II.; and a closure of the distal end may be designated by an *l* (loop).

This method of formulation of the sole configuration was first attempted in 1904[1] in making comparisons of the sole prints of different human races. In this article, in addition to the formulæ, as just described, certain exponent letters with an arbitrary significance were employed to qualify the more general terms. The presence of a hypothenar pattern (usually represented by a single loop) upon the outer edge of the foot proximal to the interdigital row, was also indicated by a capital *H*, added to the rest.

Representative sole formulæ, taken from this article, are here given. The main symbols will be readily understood from the foregoing; the meaning of the descriptive exponents, which are of less value, may be found by referring to the article, pp. 253–254.

W	*O*	*O*	*O*	
A	*OCl*	*Cl*	*O*	
A.	*O*	+ 3*Cl*	+ 2*O*	*H*
Wsp	+ 3	*Cl*	+ 1	
B	+ 3	*Cl* + 3	+ 1 + 2	

In the *first* of these the hallucal pattern is a whorl, while the three succeeding areas are open fields, without patterns. The

[1] *Amer. Anthropol.*

second has an "*A*-loop," the commonest form of hallucal pattern, where the pattern is closed, except at the interval between the great toe and the next, where the ridges run up and attain the margin; the second area, II, has a proximal loop, probably with triradius, which confines a part of the ridges. In the *third* formula some of the ridges run in the form of a U between areas 2 and 3, and in the *fourth* a similar union involves all the ridges of areas 1 and 3. The *fifth* notes an unusual form of hallucal pattern, together with a strange mix-up in the union of areas, which will become plain from the explanation of the rest.

This method of formulating sole configuration is by no means an ideal one, but it serves fairly well the general purpose of picturing the configuration of a given sole in a few terms. A fundamentally different method has been introduced by Schlaginhaufen (1905), based upon the identity of the various triradii occurring on the sole. Each one of these is designated by an abbreviation, like "*t*9" or "*t*13," and the description is based upon the position and relations of these. This method is thus a method of description rather than a formulation, and although in many ways convenient, it depends upon absolutely exact homologies, which, in our present state of knowledge, is not possible. It thus seems better to rely upon some artificial method, which is capable of picturing the essential details of a given sole, rather than to attempt a series of homologies based upon our present incomplete knowledge.

The two proximal patterns, thenar and hypothenar, have naturally suffered much displacement from the peculiar lengthening of the proximal part of the foot to form the human heel, and a discussion of their position and homologies will be found farther on in this article. Here it may be said that the transversely placed loop, sometimes seen on the outer edge of the sole, just proximal to the row of interdigital patterns across the ball, may safely be considered the hypothenar pattern, or more probably a portion of it (Fig. 7). The thenar, rare and more or less rudimentary, as in the hand, is indicated by traces of irregularity in the lines, or an occasional loop and triradius, found upon a slightly raised area upon the inner edge of the sole, not much distal to the heel (Figs. 21 and 23 below).

II. A Primitive Palm Print.

Among the prints collected from college students the past year occurred an isolated case, unique in the history of human palms thus far known (Fig. 10).

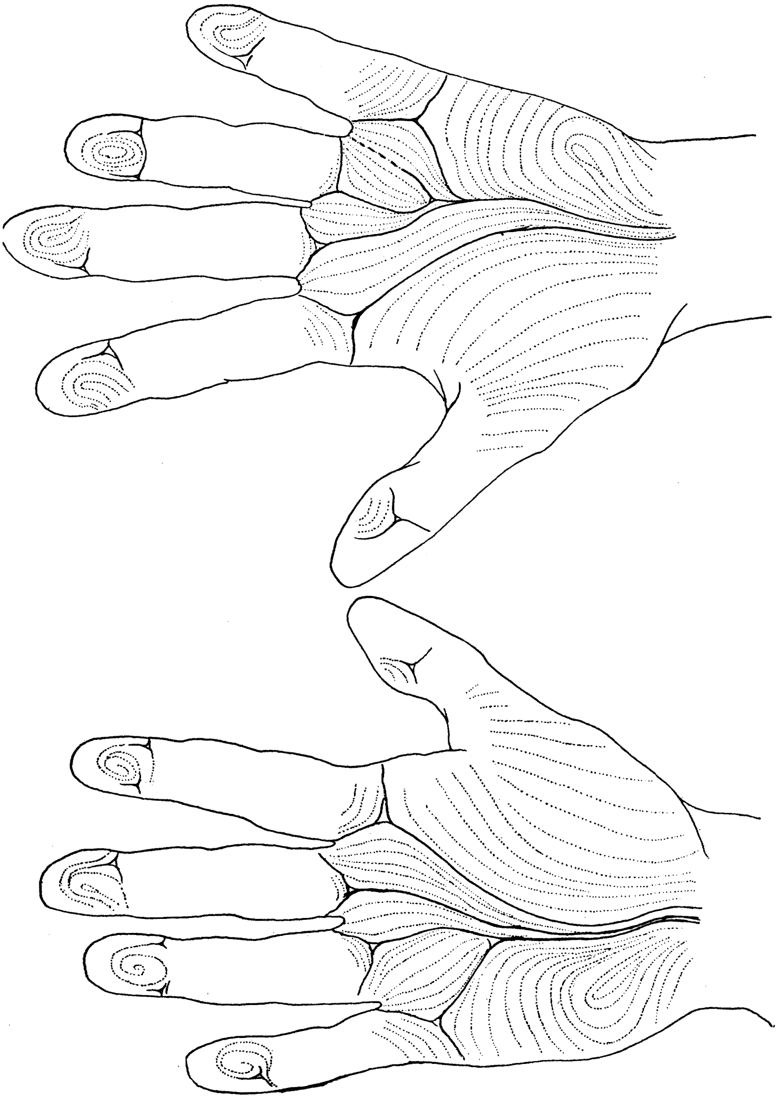


Fig. 10. Tracings taken directly from prints of the two hands of Miss ——— (Coll. No. 647), showing the simian type to a degree not even approached by any other human individual of the many hundreds thus far placed under observation by the various investigators. Formula: 1·7·1·1 or 1·1·1·1.

In the left hand of this individual, the one first noticed, all four main lines, *A*, *B*, *C*, and *D*, which proceed from the triradii at the bases of the four fingers, instead of running transversely or obliquely across the palm, as in all cases hitherto observed,

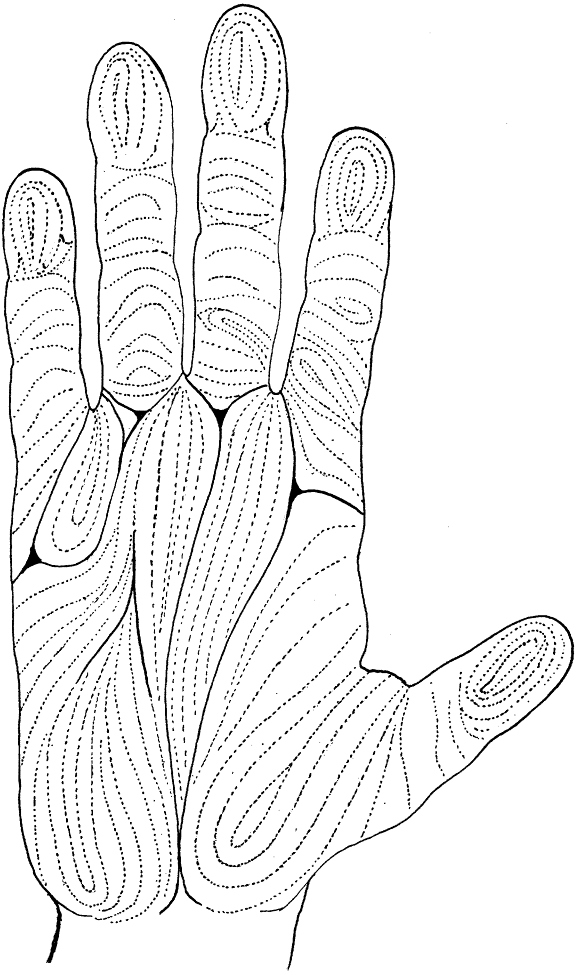


FIG. 11. Hand of a chimpanzee (*Anthropopithecus*), taken from a drawing by W. Kidd, and treated in the same way as Fig. 10, for better comparison with it. Formula: 7·6·2·2.

pass downward in a longitudinal course, and terminate near together in the middle of the wrist. This gives the unheard-of formula 2·2·2·2, if they be considered as terminating together

in a carpal triradius, or, what is still more remarkable 1·1·1·1, if they do not.

It is rather unusual, but by no means rare, to find line *A* assuming a low position along the lower third of the free outer border of the palm (position 3); several cases have been met with

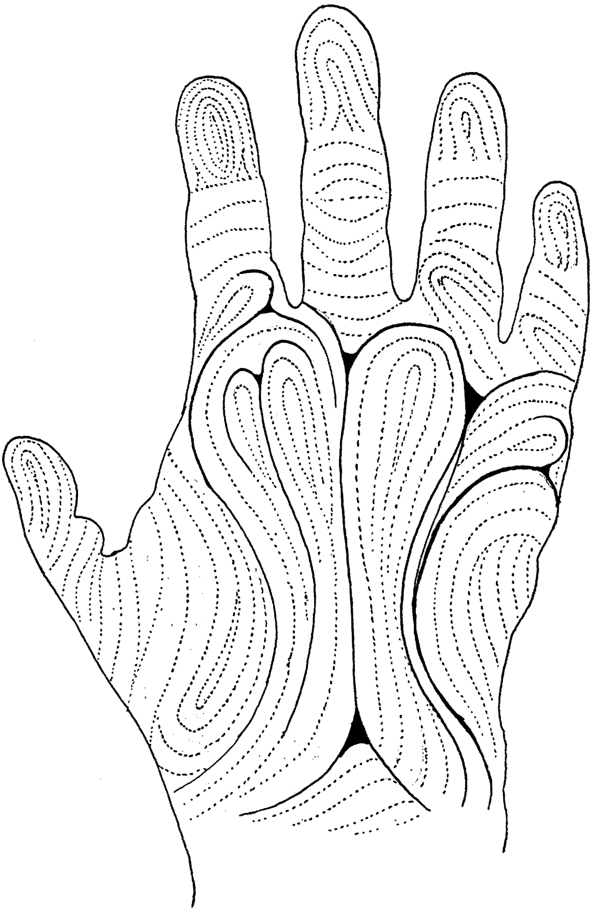


FIG. 12. Hand of a gorilla, taken from a drawing by W. Kidd and treated in the same way as Fig. 10, for better comparison with it. Formula: 3·3·2·1·(?).

in which this line reaches the carpal triradius (2); and one instance is known of line *A* terminating within (on the thumb-side of) this point (position 1); but no such course has ever been recorded for any of the other main lines, not even *B*,

which, from its propinquity to A, might be thought capable of it. Line B, at the lowest position recorded, still keeps within the upper two thirds of the outer (ulnar) margin of the palm, and thus never attains a number less than 5. The known range of line C is between 5 and 11, and D always curves up, from position 7 on, save in one rather doubtful case in which it appears to curve downwards and outwards, to reach the outer margin at 5.

The right hand of the same individual, while closely similar to the left in general appearance, introduces a slight variation in the form of a lower triradius, which confines a number of the ridges of the third interdigital area, allowing line C if one wish to so interpret it, to curve upwards and terminate at position 7, between the ring- and little-fingers. By this interpretation the course of Line C becomes quite normal, and suggests the possibility, with a slight rearrangement of lines, of fusing lines B and D, giving the total formula 10·7·6·1, which, except for the position of line A, is not at all unusual.

This right hand, much like the left but with the profound change produced by the presence of the lower triradius in the third interdigital area, suggests a partial explanation for the wholly anomalous condition of the other side, for in the left palm, at the point corresponding to the lower triradius of the right there seem to be one or two ridges that curve and suggest the last vestiges of a vanished triradius like that of the right. The presence of such a formation in this place might bring about a fusion of lines C and D, making the first two terms of the formula 6·8, yet even thus lines A and B are not explained, and remain wholly abnormal.

Whatever the explanation, the picture presented by these two palm prints, especially the left, with the ridges crossing the hand lengthwise, is strikingly like that exhibited by the large Anthropoids. This is shown in Figs. 11 and 12, put into the form of diagrams after the sketches of Kidd (1907; Figs. 48 and 46). Since, however, the figures of this author were drawings from the objects, and not print impressions, and as they were designed to show the relief, including certain of the deepest rugæ, it was often difficult to determine the exact course of the ridges, and they are not wholly trustworthy on that account. The similarity

of these to the case here presented is obvious; they may even be formulated by the method devised for human palms, the formula being, respectively 7·6·2·2 and 3·3·2·1.

The family to which the subject of this sketch belongs, No. 647 of my collection, is of good old English ancestry, and numbers among her near relatives several persons of more than ordinary distinction. The subject herself is an attractive young person of excellent mind, graduating from college with distinction, and having nothing at all abnormal about her, save this singular arrangement of the palmar friction-ridges.

An investigation of the hand prints of both parents, revealed typical European racial characters, such as the formula 11·9·7·5 in the right hand of the father and the left of the mother; the father's left hand bears the formula 11·7·7·4, and the mother's right is 11·11·9·5, a little unusual but quite normal for a white person.

Unfortunately, owing to the prejudice of the family, I was not permitted to obtain sole-prints of either the subject herself or of her parents, and consequently can make no further report.

III. The Border Region of the Plantar Friction-Skin.

Unlike the condition in the hand, where the friction-skin of the palm terminates along the borders of the contact surface, the friction-skin of the foot extends up along its sides considerably beyond the physiological sole. Since friction-skin has little or no pigment, this extension upwards gives the feet of dark-skinned races, when barefooted, the well-known appearance of pink slippers worn over black stockings.

It thus happens that, while in the hand a simple contact print includes practically the entire friction-skin area, a similar print of the foot includes only the inner portion of the ridged skin, leaving an appreciable border entirely around the part printed, concerning which no record is made. The relation of this *tread-area*, the usual extent of a print, to the entire surface covered with friction-skin is shown in a few examples here, and convinces one immediately of the insufficiency of a tread-area print (Figs. 13 and 14).

The most common loss is that of the loop upon the outer edge of the sole, the probable equivalent of the hypothenar, or of a part of it. This loop is extremely frequent, but as its center occurs

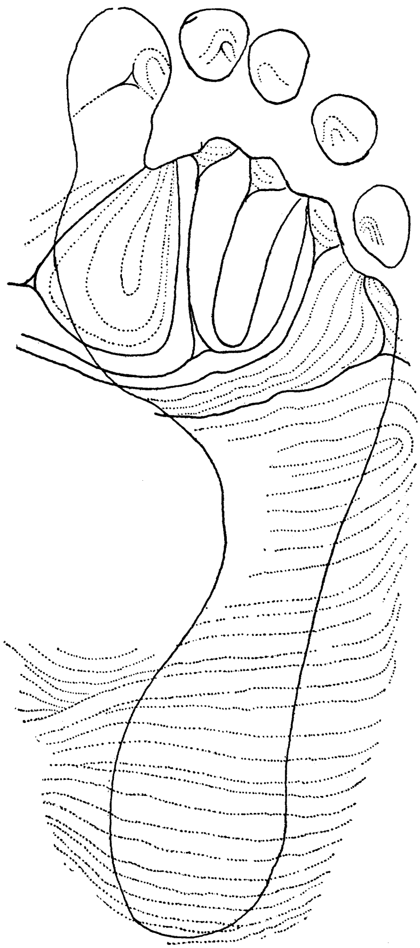


FIG. 13. Print of right foot of Coll. No. 22, showing hypothenar loop, and thenar rudiment, both outside of the tread area.

near the hypothenar edge, it is more than likely to fall just beyond the edge of a tread-area print. Thus, when completely printed, Figs. 13 and 15 are alike in respect to the loop in question, but with ordinary tread area prints the loop in the former would escape observation. In Fig. 16 a single hypothenar loop would be evident in a tread-area print, but it would never be mistrusted

that there was a second loop proximal to the other, or that the two were separated by a triradius; in Fig. 17, closely similar to 16, a tread-area print would show simply an uninteresting sole,

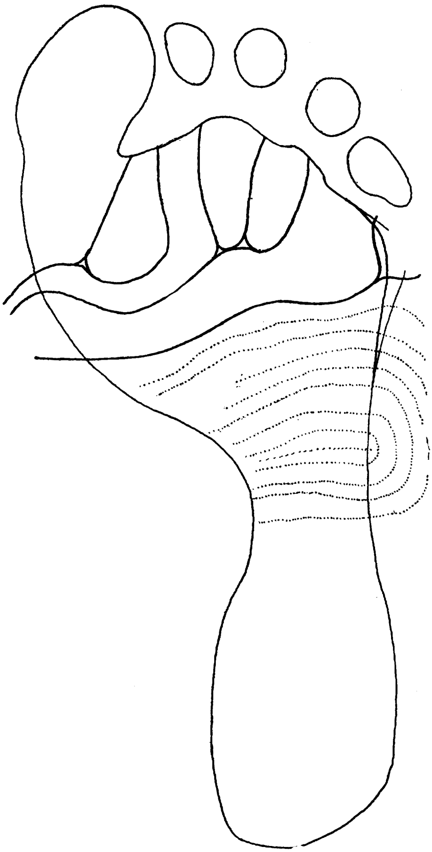


FIG. 14.

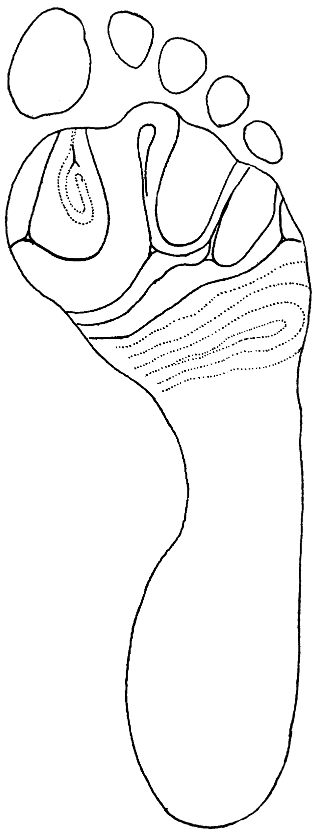


FIG. 15.

FIG. 14. Print of right foot of Coll. No. 202, showing extensive hypothenar loop, not shown by an ordinary tread area print.

FIG. 15. Print of right foot of Coll. No. 609, showing hypothenar loop, practically identical with that of Fig. 13, but so placed that it appears in a tread area print.

devoid of all special features, and would fail to show either hypothenar loop or the triradius between them.

Thus far, in the history of the investigation of human soles, there have been on record but three cases in which the general surface of the sole, proximal to the ball of the foot, shows a

pattern—a West African negro,[1] a Pole,[2] and a Liberian negro.[3] For the sake of comparison they are all reproduced here (Figs. 18, 19, 20), that of the Liberian being completed in theory

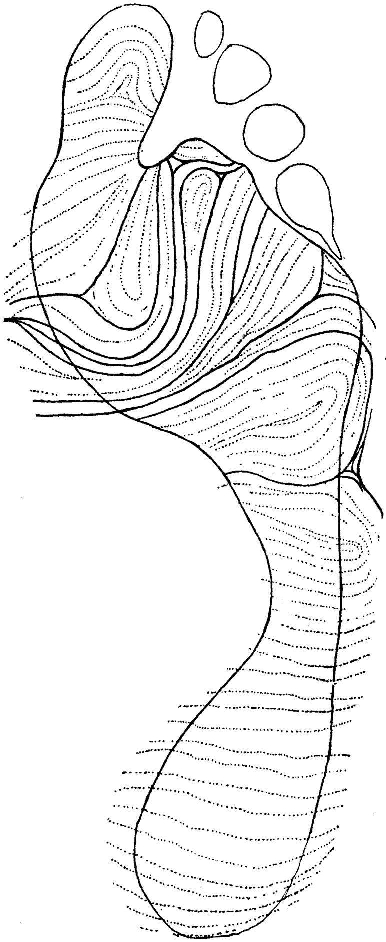


FIG. 16.

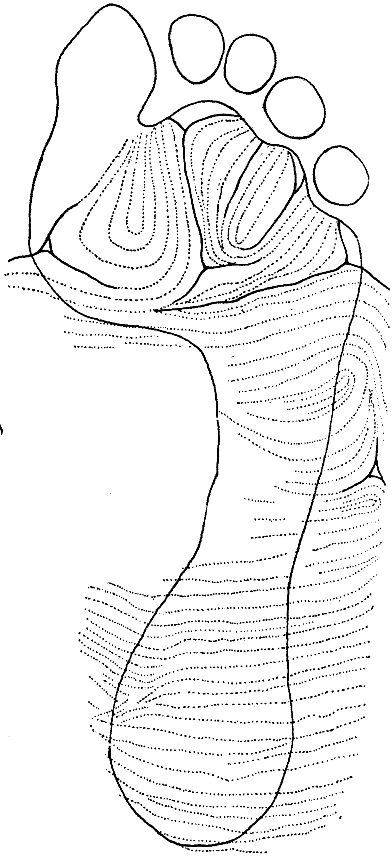


FIG. 17.

FIG. 16. Print of right foot of Coll. No. 236, showing two hypothenar loops and a large triradius. An ordinary tread area print would show only the more distal of the two loops, and present a sole, in this particular like Fig. 15.

FIG. 17. Print of the right foot of Coll. No. 183, like Fig. 16, with the addition of a thenar rudiment, the most of which would remain unrevealed by an ordinary print.

[1] Schlaginhaufen, 1905, p. 102.

[2] Mme. Loth, 1912, p. 603.

[3] Wilder, 1913, p. 205.

beyond the limit of the print, to show the probable course of the ridges. Now in all three cases we are dealing with loops that run across the sole, and in any one of them, if the core of the loop

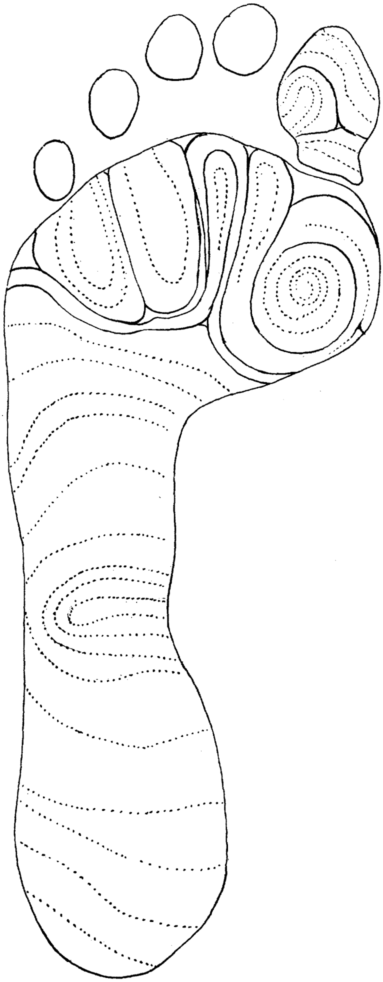


FIG. 18.

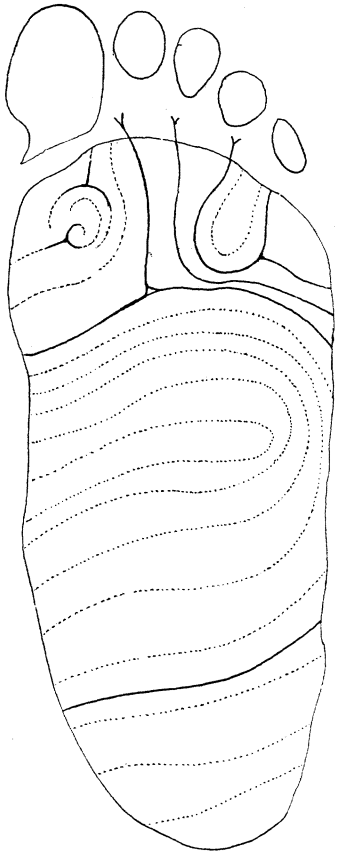


FIG. 19.

FIG. 18. Print of Schlaginhaufen's case; a West African negro, with a loop in the hollow in the foot. Both feet were practically the same. Compare with Fig. 14.

FIG. 19. Mme Loth's case; a negro from North America. Compare with Fig. 14.

had chanced to have been placed a little more laterally there would have been shown simply a sole crossed by the usual transverse lines. Even as it is, in two of the three cases, Mme.

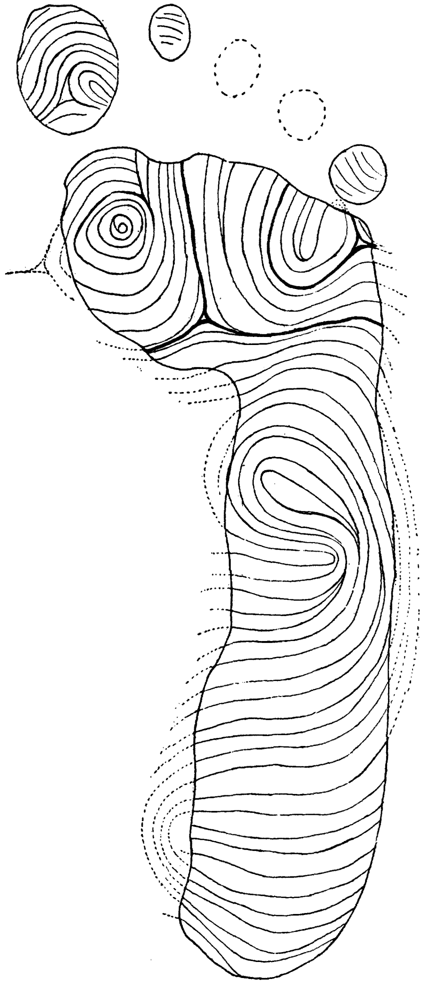


FIG. 20. Print of right foot of Liberian negro; H. H. W. Coll. No. 585, collected by F. Starr. Here the loop which corresponds with the two preceding is brought into association with a more distal one turned the other way, and perhaps, if we may believe in the theoretical completion of the figure as indicated, there is involved a third loop, more proximal than the others. Careful notice must be taken that the heavy lines of the margin, which indicate the tread area, are here all that we have, as the subject is somewhere in Liberia, and not available, and therefore, that the completion of the lines outside of this margin are wholly theoretical. In all of the other cases the lines outside of the tread area rest upon actual prints obtained by rolling the foot. This print has been previously printed (*Amer. Anthropol.*, 1913, p. 205).

Loth's and mine, the individuals were flat-footed and the prints were broader than usual, so that if the feet had had the customary height of arch these figures would have lacked in extent, and in the case of the Liberian the loop upon the inner side might have been entirely lost.

It thus forcibly suggests itself that such patterns as the three just considered *may not be as rare as has been thought, but that many of the prints of the usual monotonous type, consisting, through the middle of the foot, of transverse parallel lines without special features, might yield interesting results if the entire friction-skin area were included.*

Some years ago I attempted to remedy this defect by rolling the foot while being printed, first to the outer, and then to the inner, side, but while this proved fairly satisfactory for the outer portion, the hollow part of the sole, upon the inner side, still remained unprinted, and left a large oval area without record. Schlaginhaufen also, who devoted some study to this hollow region in his extensive work on the Planta (1905) has later sought to include in his records these neglected parts, and has places in his printed record sheet for (1) the tread area, (2) the rolled outer edge, (3) the inner hollow of the foot, and (4) the back of the heel, thus making the record a complete one (1912).

In my own attempts to investigate this border area of the soles I find it expedient, first, to make a careful study of the foot itself with a lens, and then to prepare prints corresponding in general to those recommended by Schlaginhaufen; but in some cases I supplement these by strips, applied to the inked foot, and extending from one triradius, or other feature, to another, in order that they may be correctly oriented. Naturally, the three-dimensional object which the friction-skin covers makes it impossible to reduce the whole to an exact plane, but by overlapping the strips, superposing them carefully at the triradii, pattern-cores, and other important places, and then tracing the whole by a thin piece of paper which covers it, such a figure as that shown here (Fig. 21) may be obtained, which is approximately correct. For the details of pattern-cores, etc., the separate slips are sufficient, but the exact orientation of these must naturally be preserved.

Prints of the tread-area and of the rolled outer edge are obtained in the usual way, by the use of an inked surface, upon which the part to be printed is first placed, and then placed, in the same way, upon a piece of white paper; but the strips used for details, or those covering curved surfaces, are best printed by first inking

FIG. 21. Print of right foot of Coll. No. 87, reconstructed from impressions taken of various areas. Here the arch is very high and the tread area, indicated by the entire line, is very inadequate. This is one of the few cases known which show a *calcar* pattern, here, as elsewhere, consisting of a single loop on the heel, open to the tibial side, and slanted somewhat distally, thus coming into close relation with the *thenar* pattern, covering the small thenar eminence. This latter pattern is also in the form of a loop, with its opening directed fibulo-distally, and is supplied with a triradius.

the foot and then putting on the slips, applied something like bandages, and pressed with the hand. To ink the foot the roller used in inking the paper surface may be employed, care being taken to spread the ink evenly and not too thickly. The applied strip may be pressed or gently rubbed with the hand.

One of the chief gains resulting from the study of the completed

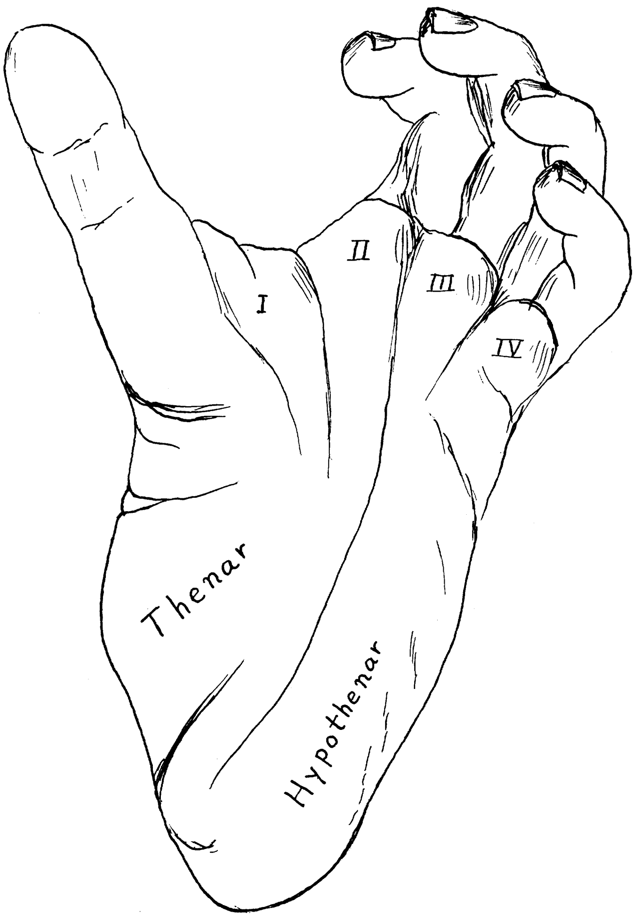


FIG. 22. Drawing of the plantar aspect of the right foot of a chimpanzee, to show the normal position and relations of the four interdigital and the two proximal pads. For comparison with Fig. 23.

friction-skin of the foot lies in the added material furnished for the study of the proximal row of patterns, the *thenar* and the

hypothenar. The long, extended heel of the human foot is so unlike anything found in typical mammals that even the location in the human subject of these once important eminences, with their associated patterns, is by no means a simple matter. The

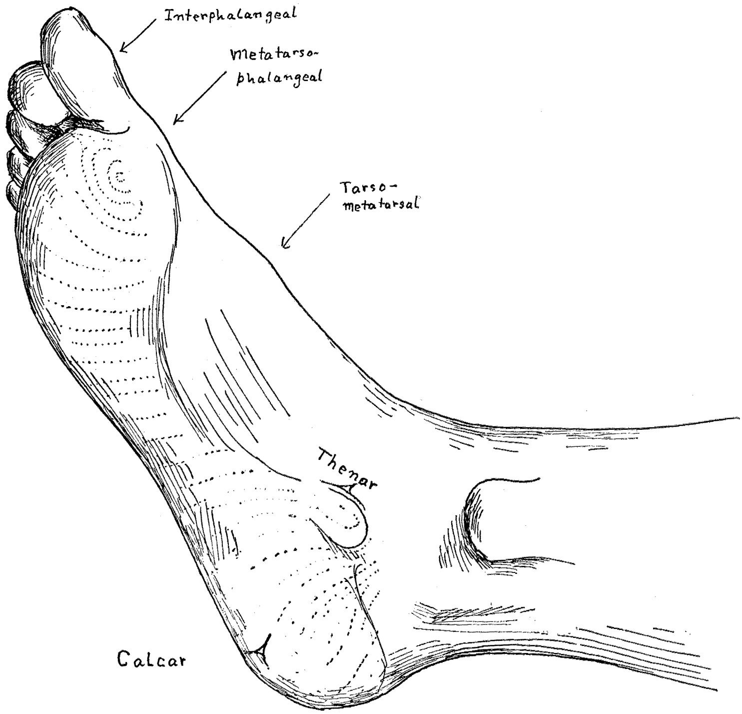


FIG. 23. Diagrammatic drawing of a right human foot, resting upon the heel, as seen in a recumbent figure; inner (tibial) aspect. The thenar pad is exaggerated, but accurately located. For comparison with Fig. 22.

best aid here comes from the comparison of the human foot with that of some one of the large Anthropoids, preferably a Chimpanzee (Fig. 22), where both the thenar and hypothenar are still evident, although the drawing-out process has already commenced. The backward extension seems here to involve mainly the hypothenar region, and as this surmise is supported by the relation of the underlying skeletal parts, we may look upon *the entire human sole*, back of the "ball of the foot," *i. e.*, the interdigital pads, *as an extended hypothenar.* The thenar seems to take no part in the extension, but lies passively upon the medial

side of the foot, quite above the tread area, where in man it may still be found greatly reduced in size and importance, but occasionally quite evident (Fig. 23).

Difficult to even locate at first, one soon becomes accustomed to picking out the thenar pad on almost any foot, and in cases where it is really prominent, and when seen in the right light, it forms a conspicuous object. The friction-ridges crossing this eminence almost always exhibit some disturbance of their otherwise even course across the foot, and occasionally show a distant loop with a triradius (Fig. 21). As is to be expected, too, the best developed patterns are likely to occur on the most conspicuous pads, the atavistic tendency manifesting itself in these two ways at the same time. The last vestige of the thenar pattern is indicated upon a flat surface, without trace of a pad, by a slight disturbance of the friction-ridges in this place (Figs. 13, 17, 24, and 25).

Miss Whipple, in her fundamental work upon the whole subject of epidermic ridges, has considered the causes of the degeneration of the thenar pad of man and finds the principal one in the establishment of the long arch, spanning the distance between the ball and the heel. The thenar pad, and, as she states, the hypothenar also, are both situated directly beneath the center of the long arch, and their reduction thus becomes a matter of necessity.[1] Schlaginhaufen[2] gives several prints of the thenar pattern, without definitely designating it as such, and was quite right in stating that he was the first to carefully investigate this pattern. In its best developed form this thenar pattern, as thus far recorded, seems to consist of a simple loop with a single triradius (Fig. 21), or occasionally, two loops, with the triradius between them.[3]

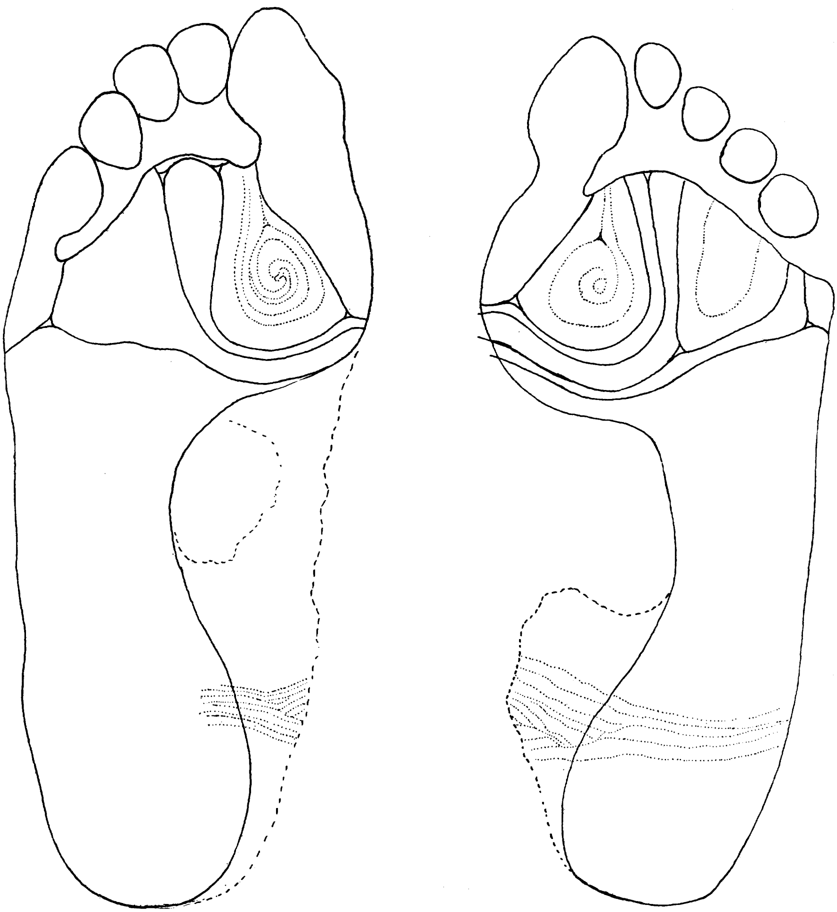
Light is shed upon the question of the hypothenar pattern by the interpretation of the long-extended human sole as formed from the hypothenar region, since, if this be true, the pattern, or elements of it, may thus be looked for on any part of this area. This would determine at once as hypothenar, not only the narrow loop found quite commonly upon the fibular edge of the foot, a

[1] Cf. Miss Whipple, 1904, p. 292, Fig. 19.

[2] 1905, pp. 107–109, Figs. 182–184.

[3] Schlaginhaufen, *loc. cit.*, Fig. 183, 1.

little proximal to the ball (Figs. 13, 14, 15) but also the second loop further back (Figs. 16 and 17), and probably also the enormous figure found in the middle of the arch in the three special cases mentioned (Figs. 18, 19, 20). Aside from these three



FIGS. 24 and 25. Prints of the two soles of the same individual (Coll. No. 199), in which an inward rolling of the feet reveals on both sides a rudimentary thenar pattern.

elements there is also the *calcar* pattern, which, aside from a single family, in which it occurs in father, mother and two of the three children, I have seen but twice. (See below, Part VI.)

Now, at the present state of our knowledge it is impossible to

say whether all of these patterns, or pattern fragments, are parts of a single hypothenar pattern, which has become spread out, and its parts disassociated, by the great extension of the part covered by it, or whether there are added to the genuine hypothenar elements certain "secondary patterns" (Whipple), like those covering the proximal and medial phalangeal surfaces in certain apes. The *calcar* pattern is treated as a secondary one by Miss Whipple,[1] and is figured in two specimens of *Cebus*, where it appears definitely distinct from thenar and hypothenar, although in contact with both.[2] On the other hand it involves no improbability to treat all of these elements, with the possible exceptions of the calcar, as the more or less disassociated parts of a long-drawn-out hypothenar, the result of a great extension of its field in one direction and finds a close analogy in the apical patterns of the four lesser toes in the human foot, where the pattern is drawn out laterally to such an extent that there occur not only long extended S-shaped figures, with the two loops far apart, but even those with three loops and three associated triradii. One of the latter is figured by Schlaginhaufen,[3] and the same type is described briefly by Miss Whipple,[4] where "the pattern has become separated into distinct loops and an accessory degeneration triradius is introduced, that is, a triradius not originally present in the typical scheme but formed incidentally in the process of degeneration of the pattern."

It is thus *a priori* probable that the three elements represented by (1) the simple hypothenar loop of the fibular side (Fig. 13), (2) the second loop occasionally present proximal to the latter (Fig. 16), and (3) the large loop in the middle of the foot, of which but three instances have thus far been described (Figs. 18, 19 and 20), are all parts of a degenerated hypothenar, yet the homologies of these several elements with one another, and the course of degeneration in the original hypothenar pattern, with the interpretation of these various existing vestiges, is still a large problem. For this there is great need of more data, complete prints of the soles of a large number of individuals, each one including the border areas of the friction-skin, with the

[1] 1904, p. 361; Taf. VI.

[2] P. 334, Fig. 37, *b* and *c*.

[3] 1905, p. 114, Fig. 185.

[4] 1904, pp. 352–353.

portions so taken that recognizable features of the usual tread area are included, to allow definite orientation.

From the few sole prints given here there are certain deductions and surmises concerning these possible hypothenar elements, that are at once apparent, and may be here mentioned, rather as suggestions to stimulate comparison than as definite assertions.

1. All the elements here considered are loops, and, with the exception of one of the loops of Fig. 20, all open toward the medial, or tibial, margin of the sole. It is thus difficult to explain them as the two disassociated ends of a long S-shaped figure.

2. In the case of Fig. 16, with two large loops facing the same way, the more distal is probably the loop commonly found on the outer margin, near the ball of the foot, while the other is readily comparable with the large loop in the hollow of the foot, as given in the cases of Schlaginhaufen and Mme. Loth (Figs. 18 and 19). If, however, we compare Fig. 16 with Fig. 17, we see this same proximal loop gradually reduced to a small but evident figure, on the way towards extinction. This gives us a series, Figs. 19, 18, 16 and 17, in which a loop begins with occupying almost the entire sole, and ends as a rudiment. One recalls here Schlaginhaufen's interesting series, in part theoretical, in which he derives such a case as that of Mme. Loth, from a moderate-sized loop, found in lower Primates, which crosses the heel region obliquely, and opens to the medial side (Schlaginhaufen, loc. cit., p. 121).

3. Concerning the calcar pattern, about which so little is known, a pattern which has been observed here and there, but has as yet no morphological interpretation, I made recently more careful studies upon No. 87 of my collection, a subject who has a good calcar pattern upon each heel. The result of this, in the case of the right foot, where there is also a good thenar pattern, is given in Fig. 21 above. In the figure the whole record of the friction-skin of the foot is spread out as reduced to a plane, and the tread area is indicated by lines. Unfortunately there are no indications of the loops here considered hypothenar, so that a comparison of either thenar or calcar with these is not possible; *on the other hand there is revealed a possible association of calcar with thenar, suggesting that the two form the two loops of an S-shaped pattern.* This close association of thenar and calcar patterns is not new, being shown by Miss Whipple in two speci-

mens of *Cebus*[1] and in *Inuus*,[2] but here the fields occupied by the two patterns seem more distinct. This author treats the calcar pattern as a secondary one, formed probably through the backward extension of the heel, to assist in covering the new area, and sees a proof of its recent nature from the fact that there is no trace of such a pattern in the corresponding position in *Lagothrix*, where "the calcar region is still covered by epidermic elements not yet fused into ridges."

An element to be considered in this connection, but one which adds to the confusion rather than assists in the elucidation, is the "Fersen-sinus" of Schlaginhaufen, which he figures on the heel of various Primates, the core of which usually forms a loop opening to the medial side, as in man. This he shows most typically in *Macacus* and *Hylobates*, but it appears also in *Simia*, *Gorilla*, and *Anthropopithecus*. As this author does not emphasize the homologies of the typical patterns as located upon the original pads, but compares rather the triradii and lines proceeding from them, one can hardly follow the patterns through his numerous figures.

IV. The Reduction of Line *C*.

In 1910 Edward Loth, assisted by Mme. Loth (Jadwiga Niemirycz-Lothowa), published the results of the examination of a large collection of the palm and sole prints of Russian Poles from the vicinity of Warsaw. In these they find a number of instances in which line *C*, with its triradius, is entirely wanting, and others in which the line in question is very short, and terminates, after a perfectly straight course, in a loop (cf. Figs. 33 and 34 below). These conditions, which are obviously closely related, both designates in a main line formula by the letter *x*.

With regard to previous recognition of either of these two conditions he cites Miss Whipple in her paper of 1904, and states very generously that he makes no claim to priority, yet thinks that he is the first to indicate it in formulæ.

As this condition has been so long known to me, practically from the beginning of my investigations, I felt sure that I had described it in detail somewhere, but, to my own chagrin, I can

[1] *Loc. cit.*, p. 334.

[2] P. 307.

find no direct reference to it in any of my writings. I have indicated this condition in formulæ, however, by the digit 8, the designation for the radius of origin of the missing line, intending to signify by this that it goes nowhere, yet I am quite ready to acknowledge that the meaning of this is not clear, and that Loth's use of the letter x is much clearer.

Since the condition itself is an interesting one, I have recently taken some pains to estimate its frequency. In the hands of 145 white persons (mostly Smith College students) a complete loss of line C, with its triradius, was found in both hands in four cases; in the right alone in five; and in the left alone in eight. That is, out of 145 individuals, no less than 17 of them showed a complete loss of the C line in one or both hands; or, put another way, out of 290 separate hands 21 were thus marked. In addition to these, nine more individuals possessed in one hand a very short and straight C line, ending in a loop, and as these were none of them duplicate individuals with any of the above or with each other, this gives a total of 26 individuals out of the 145 in which the term x $(= 8)$ occurs in one or both of the hand formulæ as a designation of the condition of line C; that is, nearly 18 per cent.

Comparing the palms of races other than white I found eight cases in 42 palms of the Maya Indians of Yucatan, or 19 per cent. much as in the whites, while in 118 palms of Liberian soldiers this condition (including both forms of it) occured but 10 times, 11.8 per cent.

To summarize these results: the condition of line C, in which it is either wholly absent, together with its triradius, or very short and ends in a loop, is a fairly common one, apparently in all races. In the negro palm, however, the marked tendency of all the lines to run diagonally across the palm, from the bases of the fingers to a more proximal position on the ulnar margin, which results so commonly in the formula 7·5·5·5, considerably lessens the percentage of occurrence of this condition.

In expressing this condition in a formula I would suggest the general adoption of Loth's abbreviation, x, when the line and triradius are both wanting, and that of 8, my usage hitherto, to designate a very short C line, ending in a loop.

(To be continued.)